FABRICATION OF Ti-CNT COMPOSITES THROUGH POWDER METALLURGY

P.S. Kulkarni[1] and S. Ratnaparkhi[2]

[1]P.G. Scholar *and* [2]*Assistant Professor,*

[1,2,] *RMD Sinhgad School of engineering, Warje, Maharashtra, India.*

[1]pskulkarni29041992@gmail.com

[2]sharayuratnaparkhi.rmdssoe@sinhgad.edu

***Abstract*— This Titanium Matrix Composites (TMCs) are widely used in industries because of its wide range of properties like high Tensile Strength, corrosion resistance, good machining properties, and low Density. The Sectors where it used widely are Aerospace, Defence, Automotive as well as in all light weight components like Windows, Door frames etc. Powder Metallurgy (PM) is one of the optimized technique used to prepare the composites with desired properties. PM technique is employed in this research to develop the Ti–CNT composites. The main aim of this project is to fabricate and study the mechanical and microstructural properties of Titanium based CNT reinforced metal matrix composite. Mechanical alloying (MA) is applied to blend Ti powders and multi-walled carbon nano tubes (MWCNTs) in order to effectively reinforce the CNTs. Composites of Ti-CNT are fabricated through Powder Metallurgy by varying CNT as 0.33 wt%, 0.66 wt%, and 0.99 wt%. Fabricated Ti-CNT composites are extruded at 4500 C so as to distribute and align the CNTs in extruded direction. Finally, the extruded composites samples are investigated for the microstructure and mechanical properties and compared with the Ti sample without CNTs, Fabricated through the same method.**

***Keywords*—Titanium powder, Extrusion, MWCNT, Powder Metallurgy**

I. INTRODUCTION

Many engineering applications in the field of aerospace engineering, automobiles, electronic equipment etc. require very light material with good mechanical properties. Titanium based metal matrix composites with carbon nanotube reinforcement can be a solution for such applications. It can satisfy the requirement of light weight with very good strength. This study focuses on preparing titanium metal matrix composites with CNT reinforcements for various compositions for its mechanical properties. Ti alloys have been widely used as structural materials in aeronautical industries due to their attractive comprehensive properties, such as low density, high strength, ductility, toughness and resistance to fatigue.

Observations on the MA behaviour of CNT–Al powder mixtures in this study showed that addition of CNTs alters the grinding behaviour of Al powders, which typically agglomerates in ball milling, and that the MA process itself is also affected by the type of CNTs incorporated. While all types of the CNTs, namely SWCNTs, DWCNTs, and MWCNTs, functioned as grinding aid preventing agglomeration of Al particles, only the MWCNTs seem to have uniformly embedded into the Al particles whereas SWCNTs and DWCNTs were supposedly not dispersed fully within the matrix. These variations in MA behaviour, dependent on the types of CNTs, are ascribed to the morphological characteristics of each CNT type such as overall shape, number of carbon walls, and diameter, and specific surface area. Consequently, nanocomposites having MWCNTs as reinforcements had best structural quality, as reflected in low porosity and absence of noticeable defects, and showed significantly improved mechanical property in terms of hardness. In order to explain improved mechanical property of the CNT–Al nanocomposites despite the poor interfacial bonding between CNT and Al as predicted in theoretical works, one possible stiffening and strengthening model was suggested in which CNTs having complex shape play the role of 'latches' retarding deformation of Al matrix under external loads. It is therefore suggested that type and morphology of CNT reinforcements are important factors to be considered in preparing CNT–Al nanocomposites through powder metallurgy routes. (1)

Multi-walled carbon nanotubes reinforced AA4032 alloy nanocomposites have been successfully manufactured by high energy ball milling. TEM analysis shows that MWNTs possess high mechanical and chemical stability. MWNTs were dispersed homogeneously in the AA4032 matrix composites. Effect of milling time on grain size and lattice strain was clearly studied and there was decrease in grain size and increase in strain with increase in milling time (4)

II. OBJECTIVE

1) The main objective of this research was to fabricate Ti powder Nano composites reinforced with higher weight fraction of MWCNTs through mechanical alloying and powder metallurgy process to enhance the mechanical properties. Three weight fractions of MWCNTs 0.33%, 0.66%, and 1% were added to the matrix of al powder and blended through high energy planetary ball mill to improve the homogeneity of the reinforcement material and to reduce the agglomeration.
2) The homogeneity of MWCNTs has been successfully achieved through mechanical alloying process using high energy planetary ball milling. Similar process has not been previously applied on Ti-MWCNT

system and found effective in reinforcing the MWCNTs up to 1wt% CNTs with reduced agglomeration.

3) The specimens of Al powder and Ti-CNT composites were characterized for the microstructure and mechanical properties and compared for the effect of increasing weight fraction of CNTs, mixing medium, cold compaction, sintering temperature, and hot extrusion.

III. MATERIALS

Reinforced Ti-CNT composites were manufactured by using Powder metallurgy technique. Ti powders of coarse size as a matrix and Multiwalled Carbon Nanotubes as reinforcement. The properties of as supplied MWCNTs are given in Table.1.

TABLE 1
Properties of Mutiwalled Carbon Nano Tube

Properties	**Value**
Purity	Carbon ≥ 95%
OD*ID*L	10-30 nm×2-6nm×15-30*10^{-3}m
Melting Point	3652 – 3697 ^{0}C
Density	1.4 - 1.9 g/cc

TABLE 2
Typical properties of Ti

Properties	**Value**
Purity	≥ 95%
Size	Coarse
Melting Point	1600 - 1660 ^{0}C
Density	4.4 g/cc

IV. METHODOLOGY

Ti powder (Coarse size) and Multiwalled carbon Nano tubes were procured from different sources available in the market. The two materials were properly mixed for different composition by using ball mill to mix uniformly CNT's with Ti powder. Compacting die set up was used to compact the powder by using hydraulic press, after compacting the powder in to solid billet sintering operation was performed by varying the sintering temperature in Tubular sintering furnace. Sintered billet were extruded in extrusion setup.

A. Preparation of composite

Here, four different compositions were manufactured for the analysis. MWNT of 0 wt%, 0.33wt %, 0.66 wt%, 0.99wt%, of carbon Nano tubes was mixed with pure Ti powder. For proper depression of CNT ball mill, the process of mixing was continued for duration of 120 min at 250 rpm in order to get uniform mixing for each composition as shown in fig. 1.

Fig. 1 Ball milling set up

The mixture of a particular weight percentage of MWCNT and Pure Ti powder was compacted in the compaction setup (Die, Top Punch, Bottom Punch) assembly using a Hydraulic press machine as shown in fig.2.

Fig. 2 Die set up

Here, Different billets were formed by varying the compaction load, i.e. 350KN, 400KN, 450KN. Green billets were converted in to hard billets by sintering operation. For this process Tubular sintered Furnace is used. Sintering operation was performed at the temperatures 850°C, 900°C, 950°C, 1000°C, Sintered samples are as shown in fig.3.

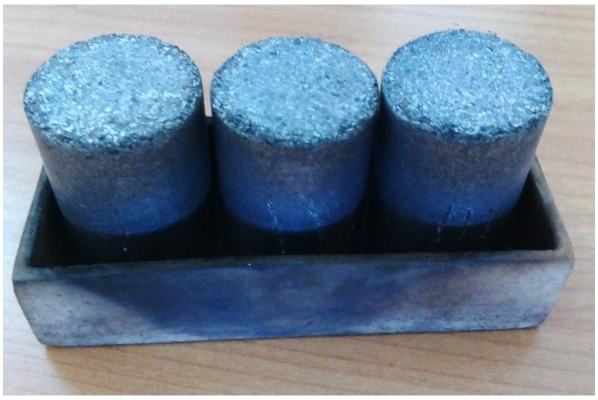

Fig. 3 Sintered Samples

Fabricated Ti-CNT composites are extruded at 800^{O}C so as to distribute and align the CNTs in extruded direction. Finally, the extruded composites samples are investigated for

mechanical properties and compared with the Ti sample without CNTs, Fabricated through the same method.
Extruded samples are as shown in fig.4.

Fig. 4 Extruded samples

V. RESULTS AND DISCUSSION

After experimentation some tests were performed and result of tests are as follows,

A. Density and porosity:

In this research Densities are calculated by two different methods i.e. Theoretical Density and Experimental Density (Archimedes' Principle). Density measured at two different stage i.e. Before Sintering (Green Density) and After Sintering. The result are tabulated in the Table.3 and Table.4

TABLE 3
Density before Sintering for pure Ti

Load (KN)	Theoretical Density (g/cc)	Experimental Density (g/cc)
350	4.47	4.43
400	4.49	4.5
450	4.55	4.56

Table.3 Shows that if we increase the compaction load Density also increase. We also observed that there is little bit difference in the Theoretical and Experimental Density for pure Ti powder. Max Density achieved in this research is 94% of Ti material manufactured by conventional method.

TABLE 4
Density after Sintering for pure Ti

Load (KN)	Experimental Density (g/cc)	Porosity (%)
350	4.41	1.343
400	4.43	1.336
450	4.5	1.099

Table.4 shows that after sintering Density decreases due to burning of lubricants and some impurity in composites. Observation about porosity is that, porosity is inversely proportional to the density. At 450 KN Porosity is only 1.099 %.

B. Hardness(HBR):

Hardness of specimen of Ti and MWCNT reinforced composites were determined by using Rockwell Hardness Testing (B scale). The results are tabulated in Table. 5

TABLE 5
Hardness of pure Ti

Temp. (° C)	Hardness at Top	Hardness at Middle	Hardness at Bottom
850	68	73	69
900	71	76	72
950	74	78	73
1000	79	82	76

It is investigated that for pure Ti, the hardness increases with increasing the Sintering Temperature up to 1000°C. Maximum Hardness achieved in this research is 73 – 82 at middle of billet. Pressure was applied on the top side so it was one directional pressure. So density is more at top and middle by properties of powder metallurgy.

TABLE 6
Hardness of Ti-CNT Composites

MWCNT wt.%	Hardness (HRB)
Ti+0	70
Ti+0.33	73
Ti+0.66	75
Ti+0.99	79

VI. CONCLUSION

Ti powder as matrix mixed with MWCNT in weight percentages of 0, 0.33, 0.66, and 0.99 %(wt) as reinforcement were produced through powder metallurgy route. The specimens were Sintered and extruded successfully. Specimens were subjected to evaluate the behavior of mechanical properties of MMC's. From the investigation, following points are concluded that Density is directly proportional to the Compaction load and porosity is inversely proportional to the Density. Hardness is increases with the sintering temperature up to 82 HRB at 1000°c. Hardness also increases with percentage of CNT's up to 79 HRB.

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